Method and device for liner system

The present invention relates to deep-water exploration drilling equipment, and more particular to a liner system according to the preamble of the appended claim 1.

A slim well is highly desirable since it reduces the costs for drilling and completion substantially. Such a well should be designed with the smallest possible diameter needed. Slim hole drilling has been used onshore for a long time. A limited application of this technique has been used in offshore applications from a floating vessel. Slim hole drilling offers a significant potential in reduction of drill cuttings discharge, reduced volume of drilling fluids, cement, casing string weight, etc. One of the main limitations when drilling in deep waters from floating drilling vessels is the size and the weight of the marine drilling riser. A slim hole allows reduction of the size and the weight of the riser. However, due to the close distance between the pore pressure curve and the fracturing curve, relatively many casing points are normally required to reach the reservoir section. So, even with conventional slim hole drilling, the weight and the size of the marine drilling riser will be significant and require a relatively costly drilling vessel to be used.

Normally, riserless drilling takes place down to the setting point for, e.g., a 20" surface casing, typically 800 m below mudline (BML). Since at this depth the risk of encountering a formation containing fluids and/or gas that may escape is increasing from this point, most deep water drilling systems are based on using a standard 18 ¾" wellhead, a 18 ¾" BOP and a 21" marine drilling riser. If fluids and/or gas should escape from the well bore, these will flow into the drilling riser and not pollute the seawater. The standard system is hereafter termed 18 ¾" wellhead system. Through the system, comprising the drilling riser, the BOP and the wellhead, the casings will be installed. As the second stage of the well bore normally a hole with a size to receive a 13 $^{3}/_{8}$" casing will be drilled. Then a third stage with a hole to receive a 9 $^{5}/_{8}$" casing will be drilled and subsequently a fourth stage to receive a 7" liner will be drilled. Finally a 7" tie-back string for production may be installed. Logging, coring and well

testing will normally be performed in a 8 ½" open hole section below the 9 5/8" casings.

Today, a 4 ¾" open hole through the reservoir section is sufficient for application of standard tools for logging, coring and well testing equipment, etc.

The problem of applying slim hole drilling on deep wells is that there is a limit on how long each section of casing reasonably can be. This puts a limitation on how deep wells that can be drilled using this technique.

The main objective of the present invention is to reduce the needed diameter of the drilling riser. This is achieved by pre-installing one or more liners below the substantial part of the drilling riser, preferably inside the surface casing, and drill the holes for these liners using underreamers after the BOP and marine drilling riser have been installed. This would allow a very small diameter riser to be used, and thus allow a low cost drilling vessel to be used.
Preferably a set of telescopic liners are installed below the well head.

The present invention thus combines the advantages of normal diameter wells (18 ¾" wellhead system) and the slim hole system.

Deep water slim hole exploration drilling using a telescopic liner system according to the present invention allows the size of the wellhead, BOP and the marine drilling riser to be reduced significantly compared to conventional 18 ¾" wellhead systems. The proposed system is preferably based on using a 10 $^3/_4$" marine drilling riser, a 9 $^1/_2$" BOP and a 9 $^1/_2$" wellhead. The system may also be termed a 9 ½" wellhead system.

According to a preferred embodiment of the invention, after the conductor casing and surface casing have been run and cemented, only liners may be used to complete the well. Consequently, no shoulder in the wellhead will be required for casing suspension. Only an arrangement for supporting the test string during well testing will be

accommodated for. This eliminates time consuming operations for running and retrieving wear bushings.

Optionally, one or more additional casings or tie-back casings can be suspended in the well head after any of the pre-installed liners have been set, which additional casing or a tie-back casing extends over and internally of the pre-installed liners, to allow for a higher pressure rating, if required. The additional casing has a smaller external diameter than the riser. In such a case a shoulder or groove in the wellhead will be needed.

The invention will be described in detail, referring to the embodiments shown in the appended drawings, wherein:

Figure 1 shows satellite well with a pre-installed telescopic liner system according to present invention,

figure 2 illustrates the cementing of the first liner of the pre-installed telescopic liner system of figure 1,

figure 3 illustrates the drilling of the hole for the second stage of the pre-installed telescopic liner system of figure 1,

figure 4 illustrates the cementing of the second liner of the pre-installed telescopic liner system of figure 1,

figure 5 shows the complete set of liners after the drilling of the well is completed,

figure 6 illustrates an embodiment of the invention using an expandable liner,

figure 7 shows a complete set of liners including an expandable liner after the drilling of the well is completed, according to a further embodiment of the invention.

Figure 1 illustrates the concept of a satellite well with a pre-installed telescopic liner system according to present invention based on using a set of pre-installed liners consisting of a 11 $^3/_4$" liner 1 and a 9 $^5/_8$" liner 2 inside a 14" surface casing 3 connected to the wellhead 9. A 5" drill string 4 with a mud motor 5, a bit 6 and an underreamer 7 is used.

In a first step a temporary guidebase 11 is installed and a bore hole 20 is drilled or jetted down to about 100 m BML (below mud line) in a conventional way without using a drilling riser and BOP. An 18 $^5/_8$ conductor casing 8 with a conductor housing 99 attached on top is then installed in the borehole 20.
Then the next hole section 40 is normally also drilled without BOP and drilling riser.

After this a unit comprising a well head 9, the 14'' surface casing 3, and a set of the telescopic liners 1, 2 is installed.

The well head 9 connected to the surface casing 3 with the pre-installed liners 1,2 suspended inside is run in hole 40 and landed in the conductor housing 99 using the drill string. Optionally, these components may also be installed separately by first installing (and cementing) the 14'' surface casing 3 and then install the telescopic liners 1, 2 inside of the 14'' surface casing with the well head 9 on top using the drill string.

The well head 9 connected to the surface casing 3 with the pre-installed liners 1,2 suspended inside the surface casing 3 can also be lowered by suspending it to the lower end of the drilling riser 10. Preferably, a blow out preventer (BOP) -100 is also installed on top of the well head 9.

The pre-installed liners 1, 2 can also be lowered by suspending it inside the lower part of the drilling riser 10. Preferably, a blow out preventer (BOP) -100 is also connected to the lower most end of the drilling riser.

The pre-installed liners 1,2 can also be lowered by suspending it to the drill string. Preferably, a blow out preventer (BOP) -100 is also connected to the wellhead.

The set of telescopic liners 1, 2 are suspended inside of the 14'' surface casing 3 by a first hanger 12 at the upper end of the 11 $^3/_4$" liner 1, gripping the inside of the 14'' surface casing 3 and a second hanger 13 at the upper end of the 9 $^5/_8$" liner 2, situated below the first hanger 12 and gripping the inside of the 11 $^3/_4$" liner 1. At the lower end of the liners 1, 2 a temporary sealing 14 is placed between the liners 1 and 2, to seal off the annulus between the liners 1 and 2.

The liners may initially be hung off in the casing by any releasable conventional hanger means, such as slips, J-slots, shear pins or similar.

The surface casing 3 will be cemented in substantially the same way as will be explained in connection with figure 2 below, and to avoid cement entering the annulus between the surface casing 3 and the first liner 1 a temporary sealing 41 is sealing the lower end of this annulus.

The drill string 4 may be lowered through the drilling riser 10, the well head 9 and the set of telescopic liners 1, 2. The mud motor 5 is situated near the lower end of the drill string 4. At the lower end of the drill string 4 the 8 ½ " drill bit 6 is connected. Just above this the 14'' underreamer drill bit (expandable bit) 7 is connected. The underreamer 7 is of a *per se* known design. It has the capacity to be retracted and expanded so that it in a retracted position has a diameter that will pass through the 9 $^5/_8$" liner 2 and in an expanded position has ha diameter of about 14''. The drill string is lowered through the drilling riser 10, the well head 9 and the set of telescopic liners 2, 3 with the underreamer 7 in retracted position. When the underreamer 7 has reached a position below the lower end of the telescopic liners 1, 2 (and preferably also below the surface casing 3) the underreamer 7 will be expanded in a *per se* known way.

Alternatively to the underreamer 7 a pre-installed core bit 15 may be used. The pre-installed bit 15 is ring shaped with an internal diameter allowing the 8 ½'' drill bit to pass, and an outer diameter of about 14''. The pre-installed bit 15 is suspended to the lower end of the set of telescopic liners 1, 2 before installing these. The suspension is

preferably done by shear pins (not shown) that may be broken when the pre-installed bit 15 is to be used, or slips that may be retracted when the pre-installed bit 15 is to be used. When the drill string 4 is lowered through the internal diameter of the pre-installed bit 15 formations (not shown), e.g., ridges, dogs or the like, on the drill bit 6 or on the lower end of the drill string 4 will interact with formations on the pre-installed bit 15 to engage the drill string 4 with the pre-installed bit 15. When the drill string 4 is further lowered or rotated the shear pins will be broken or the slips will be retracted to disengage the pre-installed bit 15 from the set of telescopic liners 1, 2. Then the pre-installed bit 15 in combination with the drill bit 6 will be used for drilling the next bore hole section 21 with a 14'' diameter for installation of the 11 $^3/_4$'' pre-installed liner 1. When this bore hole section 21 is finished, in the case of an underreamer 7 being used, the underreamer 7 will be retracted and run to the surface by the drill string 4. In the case of a pre-installed drill bit 15 being used, the drill bit 15 may be disconnected from the drill string 4, e.g., by breaking shear pins of retracting slips, in a *per se* known way, and simply be left downhole. The 8 ½'' drill bit will be able to pass through the internal diameter of the pre-installed drill bit 15 anyway, and the internal diameter may be made large enough for the 9 $^5/_8$'' liner 2 to pass.

After the drilling of the bore hole section 21, the cementing of the pre-installed liners may take place as illustrated in Figure 2. The 11 ¾'' liner is run in place using the drill string 4. To facilitate this the drill string 4 is equipped with a liner hanger running tool 16, which is designed to engage with the first hanger 12 on the 11 ¾'' liner 1, release the first hanger 12 from the surface casing 3 and hold the 11 ¾'' liner while the drill string is lowered. The 11 ¾'' liner is hung off in the surface casing 3 by the first hanger 12.

The drill string 4 is extended from the liner hanger running tool 16 to the lower end of the 11 ¾'' liner 1. A cementing shoe 17 is connected to the lower end of the drill string and connects to the lower end of the 9 $^5/_8$'' liner. The cement is conducted through the drill string 4. To avoid cement entering the annulus between the two liners 1 and 2, the annulus is sealed off at the lower end by the temporary seal 14, described in connection with figure 1. The cement flows from the cementing shoe 17 across the lower ends of

the liners 1, 2 and upwards into the annulus formed between the 11 ¾'' liner 1 and the bore hole section 21. The cement may also flow into the annulus between the 11 ¾'' liner 1 and the surface casing 3.

Figure 3 illustrates drilling of a 12 ¼" bore hole section 22 for the 9 $^5/_8$" pre-installed liner 2. After the bore hole section 22 is drilled, the 9 $^5/_8$" liner 2 is gripped by the same liner running tool 16 that was used to lower the 11 ¾'' liner 1. The lowering of the 9 $^5/_8$" liner 2 is conducted in the same way as the 11 ¾'' liner 1, and will consequently not be described in detail. After the 9 $^5/_8$" liner 2 is lowered the same cementing tool 17 is used for installation and cementing of the 9 $^5/_8$" liner 2 as for the 11 ¾'' liner 1. Figure 4 illustrates cementing of the liner 2, which is conducted in substantially the same way as for the 11 ¾'' liner 1. Finally, a 8 ½" hole (not shown) is drilled, and a 7" liner is run and cemented in a conventional way.

Figure 5 shows the complete casing program. The 18 $^5/_8$" conductor casing is set at, e.g., 2620 m MD (Measure Depth) (100 m BML) and the 14"surface casing 3 is set at 3320 m MD (800 m BML). The invention requires the use of a proper underreamer 7 that can pass through the internal diameter of the 10 ¾" riser 10, which is typically 9 ½", and through the internal diameter of the 9 $^5/_8$" liner 2, which is typically 8 ½", or a pre-installed drill bit 15. For the 11 ¾" pre-installed liner 1, a 8 ½" bit 6 and a 14" underreamer is used for drilling the hole section 21 to 4020 m MD (1500 m BML). Alternatively, the pre-installed core bit 15 can be run along with the pre-installed liners 1, 2. When the drill string 4 with the 8 ½" bit 6 is in place, the core bit 15 is connected and run along with the bit 6. After the borehole section 21 has been drilled to final depth, the core bit 15 is left in the hole and allows the 9 $^5/_8$" pre-installed liner 2 to pass through.

Alternatively to first drilling the bore hole section 21 and subsequently lowering the liner 1 into the bore hole section, it is also possible to lower the liner 1 simultaneously with the drilling. Thus, the pre-installed drill bit 15 may also be rotatable connected to the lower end of the liner 1, so that as the pre-installed drill bit 15 is churning down the formation, the liner 1 will be drawn downward, preferably without rotating.

For the 9 $^5/_8$" pre-installed liner 2, the 8 ½" drill bit with a 12 ¼" underreamer 18 (see figure 3) is used for drilling the hole section to 4720 m MD (2200 m BML). The 12 ¼'' underreamer 18 may be the same as the underreamer 7, wherein the underreamer 7 is designed to be retracted from a 14'' diameter to an intermediate position of 12 ¼'' diameter. Alternatively, the 12 ¼'' bit is a separate underreamer that replaces the underreamer 7.

After the pre-installed telescopic liners 1, 2 are installed and cemented, an 8 ½" hole section 23 is drilled for a 7" liner 19. The 7'' liner is installed through the drilling riser 10 and cemented in a conventional way. If a deeper well is needed, a 6" hole section 24 can be drilled for a 5 " liner (not shown).

Figure 6 illustrates the use of an expandable contingency liner 30. This liner is set in the 9 $^5/_8$" pre-installed liner 2, and expanded from 6,25" x 6,875" to 7,828" x 8,542". This allows a 7" liner 31 to pass through. For the 7" liner 31, an underreamer (not shown) with a diameter of 7 $^7/_8$ "to 8 ½ " is used for drilling a hole section to 5720 m MD (2500 m BML).

Figure 7 shows an alternative to a set of pre-installed telescopic liners 1, 2. In this case only one liner 32 is pre-installed below the wellhead. This liner 32 is lowered into the well bore and cemented substantially the same way as explained in connection with the 11 ¾'' liner 1 in figures 1 and 2. Thereafter a further borehole section is drilled. An expandable liner 33 is then inserted through the drilling riser 10 and the liner 32. Then the liner is cemented, expanded and set using conventional technology.
The drilling is commenced by passing a drill bit with a diameter less than the internal diameter of the liner 33. Finally, a liner, e.g., a 7'' liner 34 will be inserted through the well head, the liner 32 and the liner 33.
An expandable liner hanger can also be used for suspension and sealing of the expandable liner 33.

An expandable liner hanger can also be used both for the pre-installed liners (1, 2). A conical ring can be pre-installed at any suitable place within the liner or liner hanger. The ring shaped cone can be installed in a section of the liner or liner hanger having a smaller material thickness than the surrounding sections of the liner or liner hanger. A tool acting on the cone by mechanical or hydraulic means can be used to force the cone into the section of the liner or liner hanger having a larger material thickness. Thus, the material of the liner or liner hanger will be forced radially outward and into contact with the larger casing or liner, in a *per se* now way in connection with conventional cones without a central opening. After the expansion, the ring shaped cone is left in place, since the internal diameter is large enough to allow equipment to pass.

The wells drilled and cased according to the present invention can also be used for production. A 7" tie-back string 35 with a downhole safety valve 36 can be installed. A horizontal x-mas tree 37 can be used to land and seal a tubing hanger 38. A shoulder with an internal diameter of approximately 8.6" should be sufficient to support a 9 ¼" external diameter tubing hanger.

Compared to a standard 18 ¾" wellhead system using 21" riser, 30" conductor casing, 20" surface casing (drilled without riser), 13 $^3/_8$", 9 $^5/_8$" casing and 7" liner, the system according to the invention, using a 10 ¾" riser allows for the same number of casing points, i.e., 18 $^5/_8$"and 14" casing (drilled without riser), 11 ¾", 9 $^5/_8$" and 7" liner drilled with riser. As an option, a 6" hole can be drilled and a 5" liner can be run and cemented.

The total hook load for suspending a 800 m long 14" casing with 800 m long sections of 11 ¾" and 9 $^5/_8$" pre-installed liners using a 5", 2500 m long drill string is in the order of 250 tons. Therefore, the selected drilling rig must have sufficient hook load capacity.

Depending on selection of casing and liner sizes and grade, a pressure rating between 5000 and 10000 Psi can be obtained. By increasing the wall thickness of the 11 ¾" pre-installed liner and possible the 14" surface casing, a 10000 Psi completion is achievable.

The pressure rating of post-expanded liners is reduced, and therefore, internal casing or liners may be needed to maintain the pressure integrity of the well.

The invention allows wells to be drilled and completed using a smaller diameter drilling riser.

Combining the system with a high-pressure riser with surface BOP, the drilling riser can simply be a 10 ¾" casing without kill and choke line. This allows for fast installation and retrieval compared to conventional systems. Combining the present invention with a Low Riser Return System or Riser Lift Pump, would allow for further reduction in the number of liners and casings needed to complete the well. Using the slim riser would also allow the hole section 40 to be drilled with limited or no drill cuttings and drilling fluid discharge to sea. Using the slim riser and a Riser Lift Pump would also allow the hole section 41 to be extended significantly.

An 18 ¾" wellhead system for drilling in 2500 m of water requires a costly drilling vessel to be used. A typical cost of a large drilling vessel is in the order of 180,000 USD/day. The present invention allows for a low cost drilling vessel to be used since the volume and the weight of the marine drilling riser is only approximately 23 % of a conventional system using a 21" marine drilling riser. A typical cost of a small drilling vessel (purpose build drill ship) is in the order of 150,000 USD/day. Assuming 35 days drilling time for both systems, the potential cost saving is in the order of 1,000,000 USD.

As indicated above, the drilling operation may be performed faster by using the present invention. This will allow for further cost reduction.

Alternatively, although it is not the best embodiment of the present invention, the pre-installed liners may be installed in a lower part of the drilling riser having a larger diameter than the pre-installed liners. Above this lower part the diameter of the drilling riser can be reduced under the diameter of the pre-installed liners. The internal diameter

of the well head will of course have to be larger than the pre-installed liners. By this the substantial part of the drilling riser may have a reduced diameter.